SPACE RESEARCH LABORATORY

TECHNICAL REPORT SERIES

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DEPARTMENT OF PSYCHOLOGY
UNIVERSITY OF MARYLAND
COLLEGE PARK

TECHNICAL REPORT

No. 67-13

A COMPARISON OF FIXED RATIO AND VARIABLE RATIO PUNISHMENT WITH AND WITHOUT A WARNING SIGNAL[1]

Department of Psychology
University of Maryland

Prepared by:

David Orme-Johnson

[1]This investigation was supported by Grant No. NsG 189-61 from the National Aeronautics and Space Administration.

Abstract

Variable schedules, in which a reinforcing or punishing event occurs randomly with respect to responses or time, are more effective in some ways than the equivalent fixed schedules with the same average interval or ratio. In the present experiment variable ratio and fixed ratio punishment of variable interval responding were compared on a multiple schedule. It was found that VR 10 punishment produced a greater punishment effect than FR 10 punishment. Two possible explanations for this effect were proposed. The first explanation stresses S's being able to discriminate which response will be punished. Potentially, on FR 10 punishment S can discriminate that the 10th response will be punished while on VR 10 punishment there is no way to make such a discrimination. The second explanation stresses the discrimination of the frequency of punishers during a session on the VR vs. the FR schedule. Possible, S's "average" differently the rate of shocks received on variable and fixed schedules.

To test the first explanation, a "warning signal" for punishment was programmed to occur when the next response would be punished, making when punishment would occur easily and equally discriminable on the two schedules. If the first explanation were true, one would expect the VR - FR difference to diminish when the "warning signal" was programmed. This was not the case. It was found that with the "warning signal" VR punishment continued to produce a greater punishment effect that FR punishment and the second explanation was supported.

Recent studies comparing the effects of two different schedules, in which the frequency of reinforcement or punishment is held equivalent, have shown that the variability with which the reinforcing or punishing event occurs is an important variable. For example, Herrnstein (1964) found that pigeons preferred a discriminative stimulus (S^D) associated with food on a VI 15" food reinforcement to an S^D associated with food on an FI 15" schedule. Similarly, Fantino (1967) found that pigeons preferred a mixed FRFR schedule (which is equivalent to a VR with two values) over an FR schedule whose value was the mean of the two FRs in the mixed schedule. When Fantino varied the difference between the two FRs in the mixed schedule (while holding the mean constant) he found preference for the mixed schedule to be greatest when there was a maximum difference between the two FRs. That is, the greater the variability the greater the preference for the variable schedule.

Recently, Zill (1967) and Davis (1967) extended this "variability" effect to conditioned suppression. Both investigators found that a variable CS produced greater conditioned suppression than a fixed CS whose length was the average of the variable CSs.

In all these experiments, the variable schedule had a greater effect than the equivalent fixed schedule. The present study was designed to extend this generalization to VR and FR punishment. On the basis of the literature, it was expected that VR punishment would produce a greater response suppression than FR punishment

METHOD

Subjects

The subjects were two experimentally naive white Carneaux pigeons,

approximately 8 years old.

Apparatus

The experimental chamber was constructed from a Poloron ice chest by fitting it with a front panel equipted with a response key and feeder. The inside diameter of S's working area was 11" x 11" x 13" high. The manipulandum was a translucent Gerbrands response key mounted 9" from the cage floor and 3" from the left cage wall. A force of 8 grams operated the key and a relay "click" provided response feedback. The key was illuminated either yellow or green or was dark. Ambient illumination was provided by two white lights (GE 327) located on the front panel 5 1/2" from the cage floor and one 2" from the left cage wall and the other 2" from the right cage wall.

The reinforcer was a 3 sec. exposure to a grain mixture of 50% milo, 40% vetch and 10% hemp delivered by a Lehigh Valley feeder through a 2" x 2" opening in the center of the front panel 3" from the cage floor.

The punishing stimulus was an AC shock delivered through an 80 K resistor. The shock was delivered to the Ss by the implanted electrode technique described by Azrin (1959). The Ss resistance varied less than 5% throughout the experiment and was 1200 ohms for B4172 and 1500 ohms for B1725.

The experimental chamber was located in a closed room with ambient white masking noise. All programming equipment was located outside the experimental room.

Procedure

Ss were shaped to key peck and were then run on a VI 15" schedule for 1 session. Sessions were two hours long. They were then run on VI 45" for 1 session; VI 1' for 1 session and VI 2' for 40 sessions.

The final VI 2' schedule was that described by Hoffman and Fleshler (1965) for 60 events. A multiple schedule was in effect throughout the experiment in which 10 min. presentations of a yellow or green key color alternated being on with a 30 sec. time out between each alternation.

Initial exposure to punishment: Punishment was then introduced: VR 10 punishment when the key was yellow and the FR 10 punishment when the key was green. The VR distribution was a square distribution with a range of 3 to 16. Shock onset began 20 msec. after closure of the microswitch on the key and the duration of the shock was always 50 msecs. throughout the experiment. The intensity was initially 1 ma and was increased daily in 1 ma increments until 14 ma was reached. B4172 was run additional sessions at 0, 5, 7, 12 and 14 ma.

EXPERIMENT I - Pun ishment with and without a "warning signal".

Both subjects were then run on 6 hour and 40 min. sessions for two sessions of no shock. They were then run for 20 sessions at 7 ma, then run 8 sessions containing approximately one hour of punishment followed by 4 hours and 40 minutes of punishment with a "warning signal" followed by one hour on punishment alone. On the 9th session, punishment with a "warning signal" was run for the entire session.

The "warning signal" consisted of flashing the key light (yellow or green) at a rate of 10 Hz by running the key light ground through a Foringer # 1699 Pulse Stream Modualtor. During FR punishment the flasher was made operative by the 9th response and was terminated by the 10th response which was punished. During VR punishment, the la st unpunished response initiated the flasher and the next (and punished) response terminated it. The flasher or "warning signal" will hereafter be referred to as the "S^D" (for punishment) and is not to be confused

with the yellow and green colors which were also S^Ds and were operative throughout the experiment.

RESULTS

Figure 1 shows the results of the initial introduction of punishment. The first point at 0 ma represents the average rates for the five days previous to punishment. For B 1725, at low shock intensities (from 1-5 ma), there was little punishment effect or difference between VR and FR punishment. However, as the shock intensity was increased further, VR punishment produced a greater response decrement than FR punishment. For B4172, the second intensity series is shown. (No difference between FR and VR was found on the first series for this S). The effect is much like that for B1725, with no difference in the effects of VR and FR 5 ma shock, but with a difference developing at higher intensities.

Figures 2 and 3 show cumulative records for Ss from the 1st, 3rd and 5th hours of the last session before the S^D was added. A "V" over a record indicates VR punishment and a "F" indicates FR punishment. Event marks on the cumulative records indicate the occurrence of punishment and event marks below the records on the horizontal line represent the occurrence of reinforcements.

For both subjects VR punishment consistently produced a lower response rate than FR punishment, which is indicated by the lower "peaks" with "Vs" than "peaks" with "Fs". Also, both VR and FR punishment produced a constant decrease in response rate and no patterning effects were found during FR punishment.

Figures 4 and 5 are taken from the first day in which the S^D or "warning signal" was added. The S^D was added in the second half

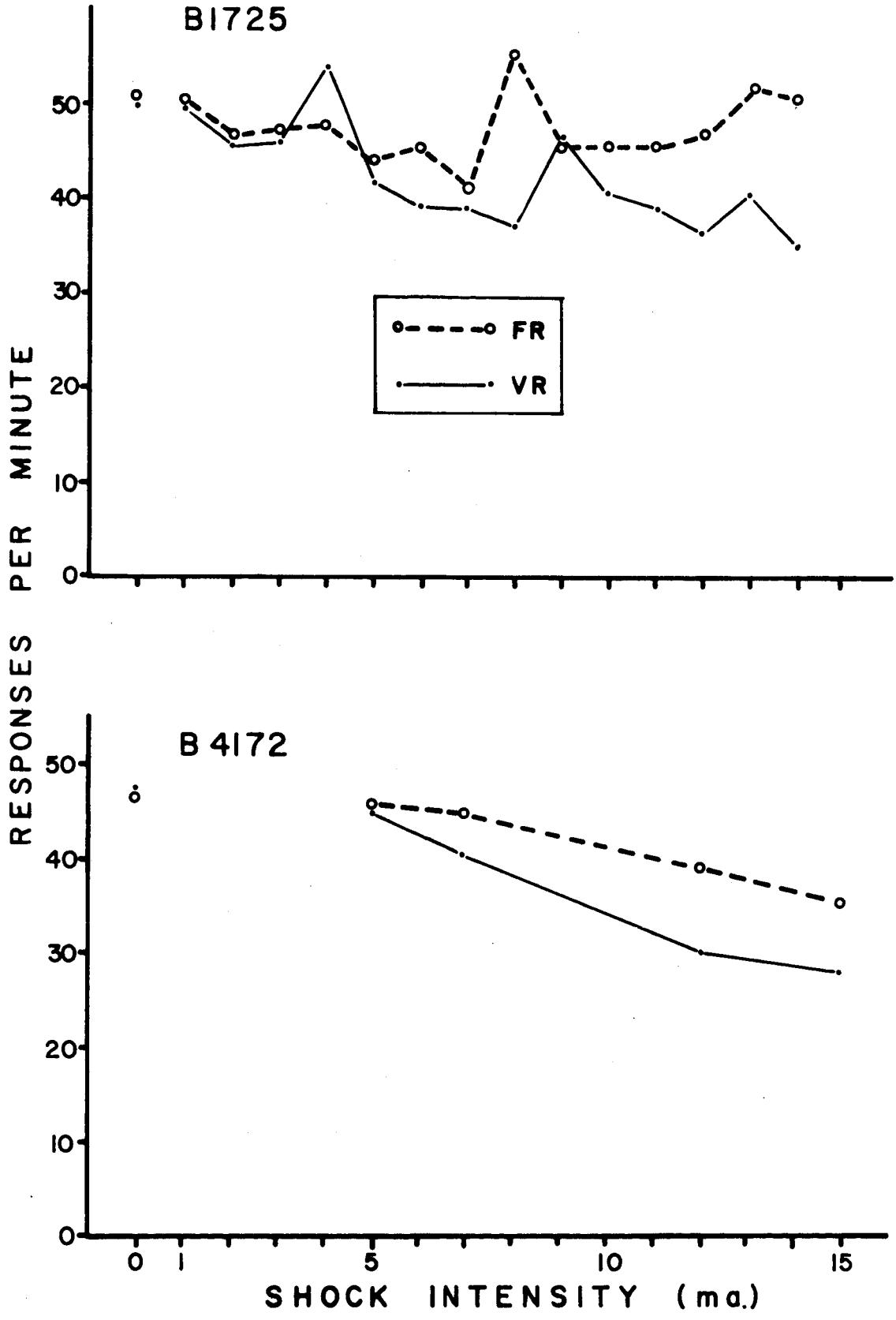

FIG. 1

Responses per minutes as a function of shock intensity for FR 10 punishment (dotted lines) and VR 10 punishment (solid lines) of VI 2' food reinforced behavior.

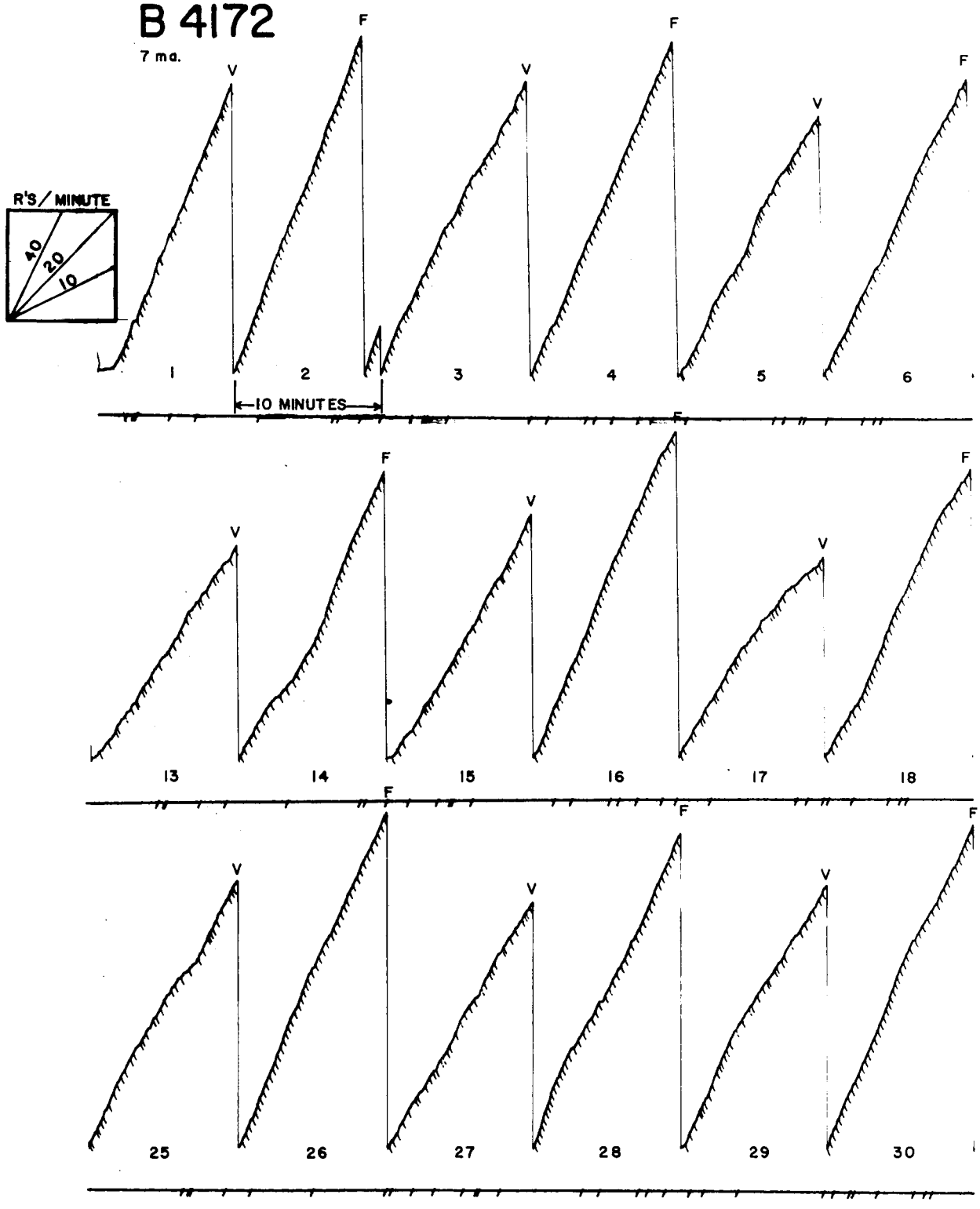

FIG. 2

Cumulative records for B4172 from the last day of punishment alone (before the warning was added).

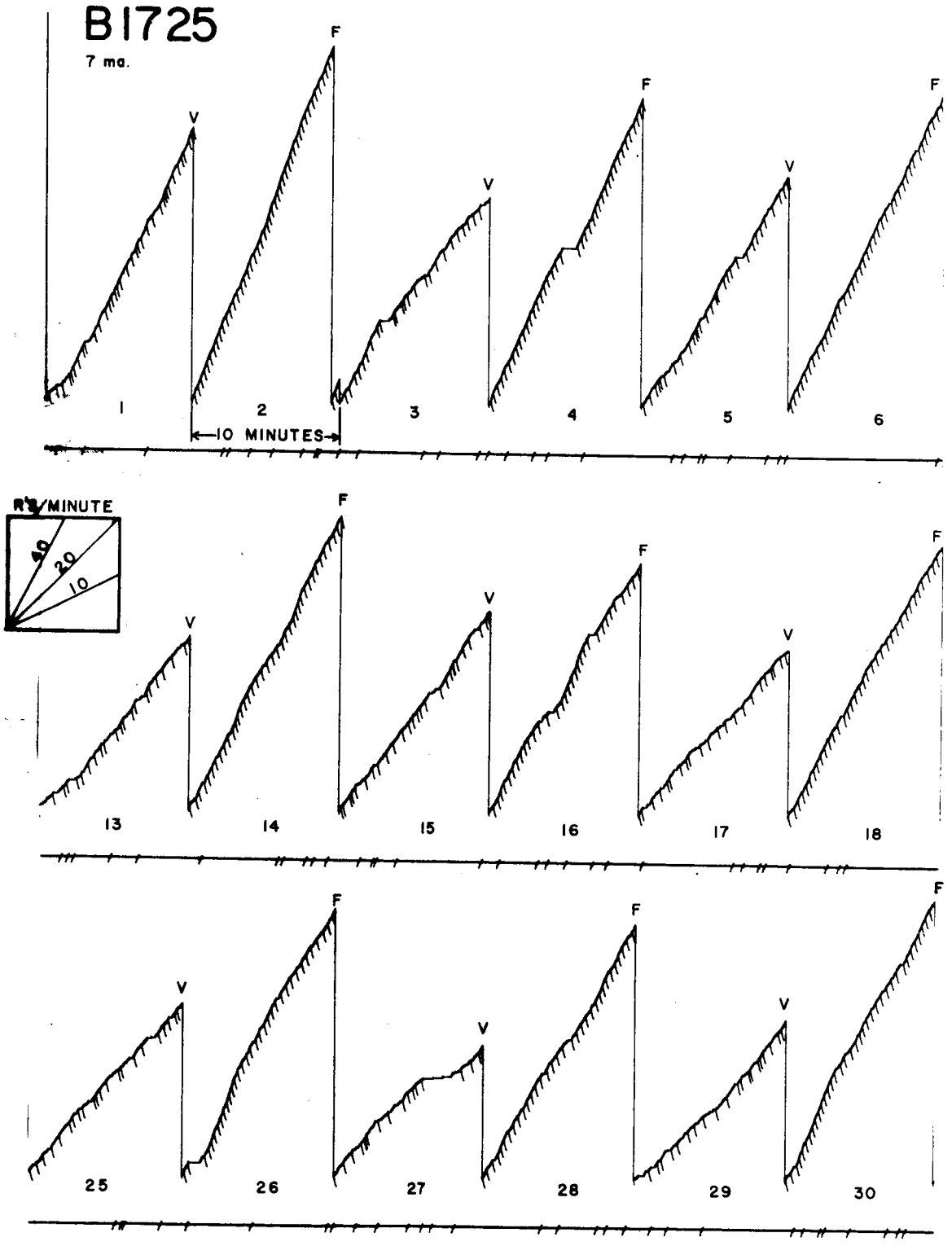

FIG. 3

Cumulative records for B1725 from the last day of punishment alone (before the warning was added).

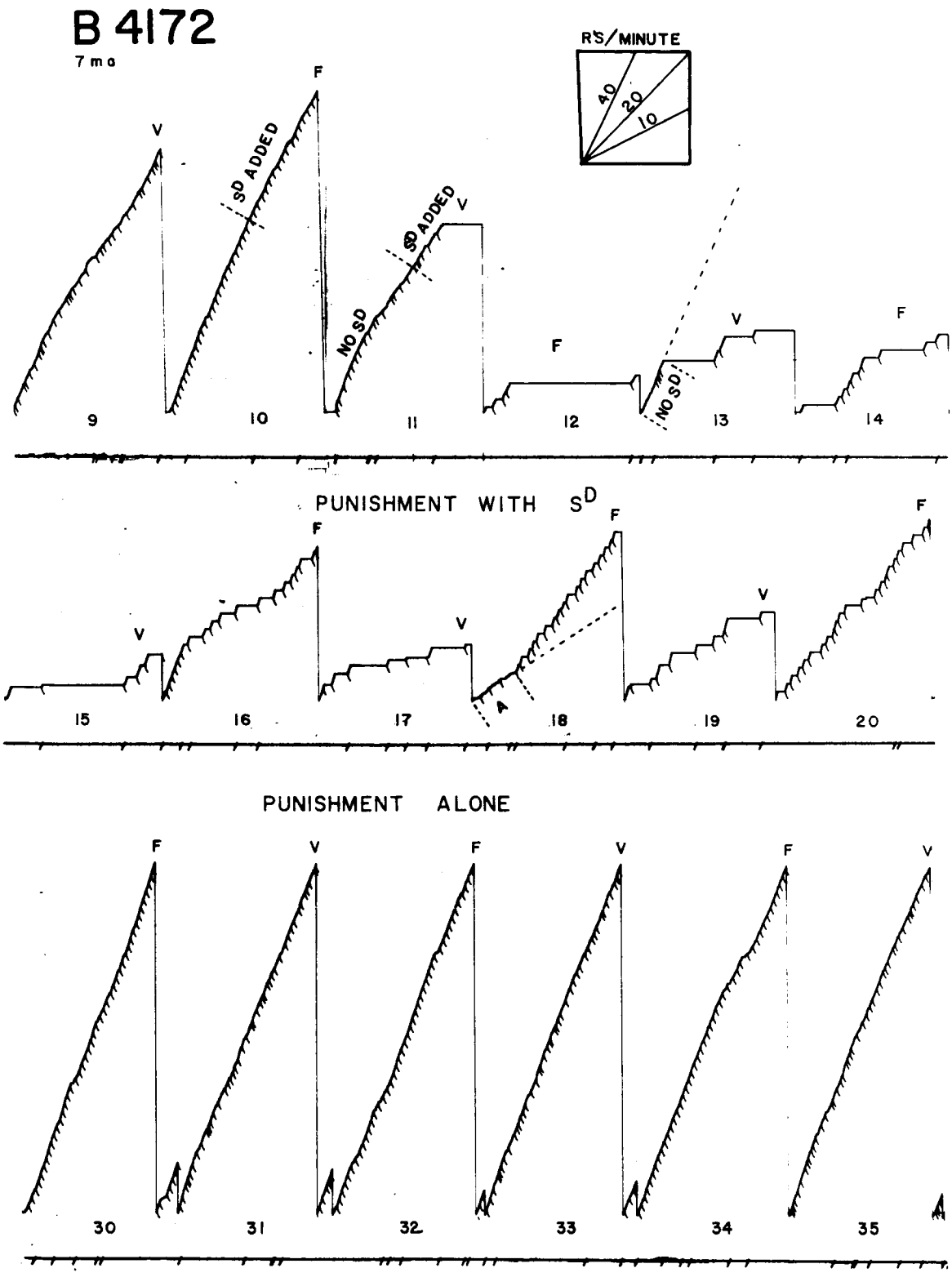

FIG. 4

Cumulative records for B4172 from the first day during which punishment with a warning (S^D) was run.

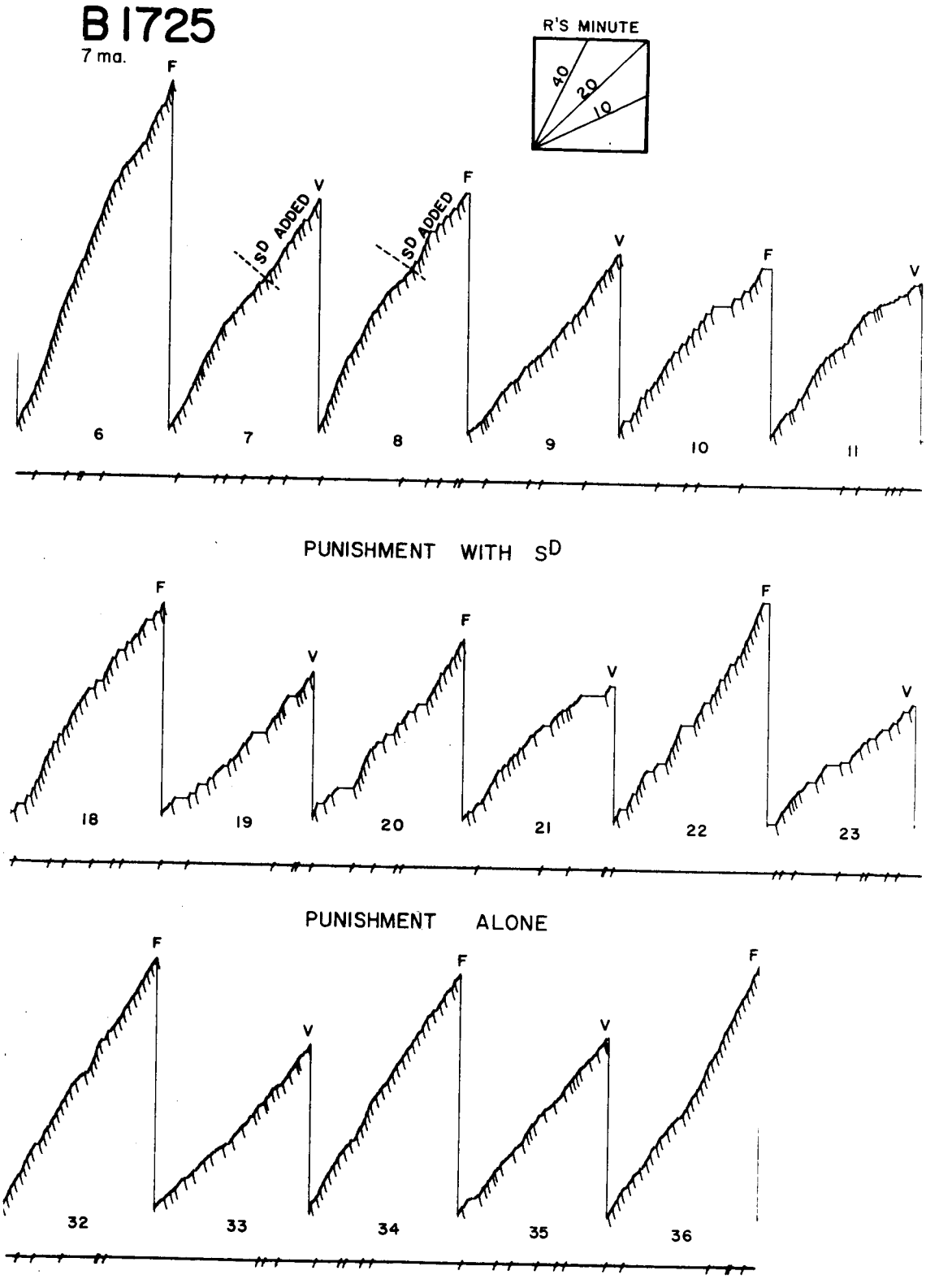

FIG. 5

Cumulative records for B1725 from the first day during which punishment with a warning (S^D) was run.

of the 10th and 11th cycles for B4172 and in the second half of the 7th and 8th cycles for B1725. The S^D was then programmed for the remainder of the session except for the last hour, in which the S^D was discontinued and punishment alone was run.

Figures 4 and 5 show that punishment with an S^D produced a greater response decrement than punishment alone for both VR and FR punishment. Furthermore, VR punishment with an S^D produced a greater rate decrement than FR punsihment with an S^D.

Figures 4 and 5 also show that during punishment with an S^D a definite pattern of "runs and breaks" developed, the "breaks", or periods of no responding, occuring during the S^D, and the "runs", or periods of responding, occurring during the "safe period", or times when the S^D for punishment was off.

In Fig. 4 during the 13th cycle, punishment alone was programmed during the part of the record marked "No S^D". A relative high rate of responding occurred during "No S^D" which was equivalent to the rate before the S^D was added (9th and 10th cycles). During the 18th cycle, Fig. 4, the flasher was on continuously (as opposed to just before punishment) during the period marked "A". The response rate during the continuous flasher was relatively low and the run and break pattern was not apparent, but this pattern reappeared after period "A".

When the S^D was discontinued in the last hour of the session, the run and break pattern disappeared for both Ss. For B4172 the difference between FR and VR punishment also disappeared, but this difference reappeared in subsequent sessions.

Figures 6 and 7 show the cumulative records for the 1st, 3rd, and 5th hours of the last (9th) session in which the entire session was run on punishment with an S^D. These figures show that the run and

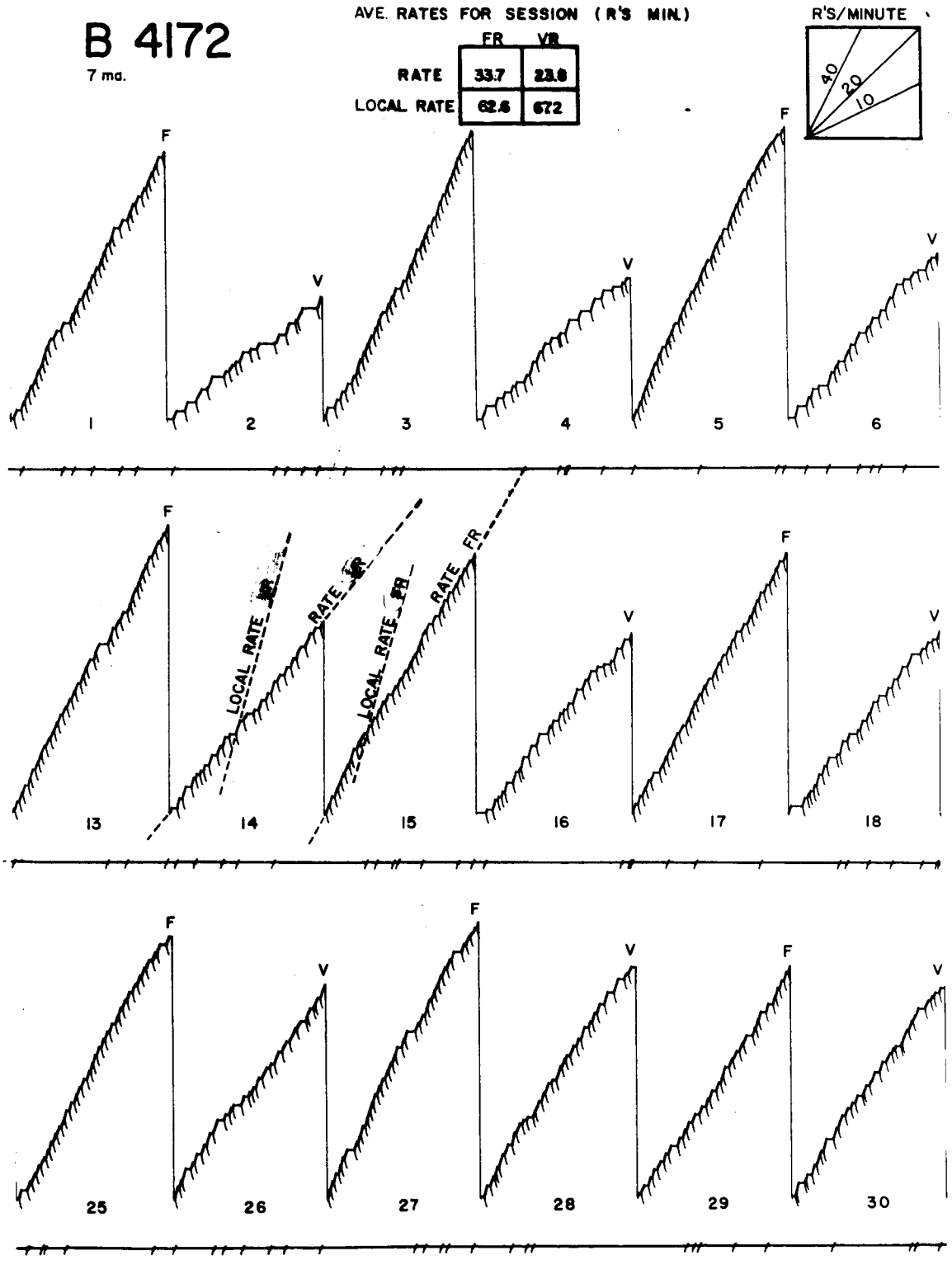

FIG. 6

Cumulative records for B4172 from the last session (9th) during which the entire session was run with punishment with a warning.

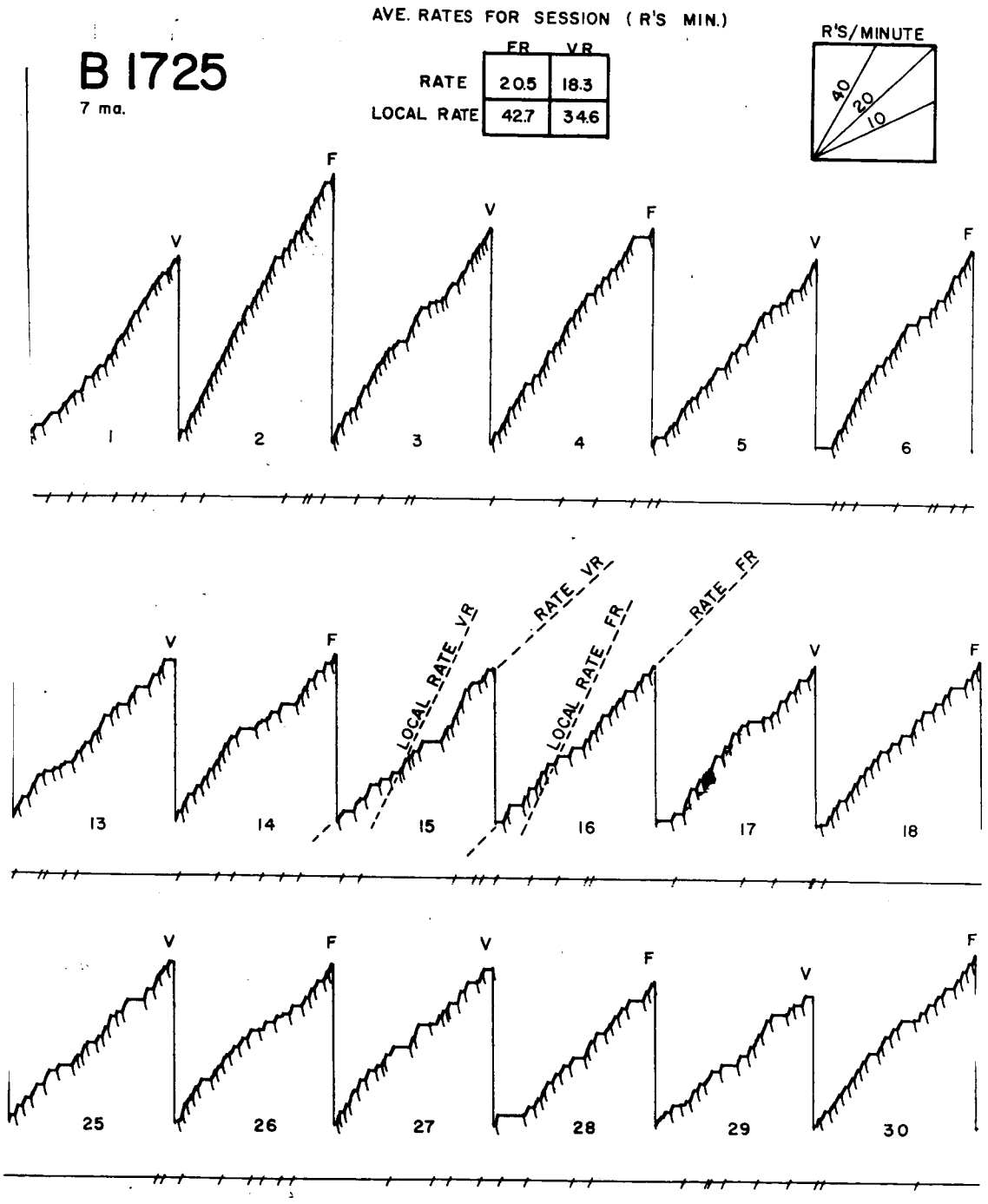

FIG. 7

Cumulative records for B1725 from the last (9th) session during which the entire session was run with punishment with a warning.

break pattern was still evident after over 40 hours of exposure to punishment with an S^D. The dotted lines extending the record during runs are marked "local rate" and show that the rate during runs is relatively high. The insert at the top of Figs. 6 and 7 show the response rates in responses per minute for the local rate as well as for the overall rate marked "rate". The local rate was calculated by determing the total time during the safe periods for VR or FR in a session and dividing this into the total responses in the session for VR or FR. The local rate was approximately twice as high as the rate. In addition, the overall rate for FR was higher than the overall rate for VR.

Table 1 gives the response rates in responses per minute for the 8 sessions in which punishment with and without an S^D were run. Punishment alone rates are the average from the first hour of each session when no S^D was programmed. During punishment with an S^D, two rates are given, the"rate"and the"local rate", which are illustrated in Figs. 6 and 7. This table allows many comparisons. For example, it can be seen that the VR rates are lower than the equivalent FR rates. Also, it can be seen that whereas the overall rates during punsihment with an S^D were lower than rates for punishment alone, that the local rates for punishment with an S^D were higher.

EXPERIMENT II

This experiment was designed to further explore the relationship between shock intensity and the relative VR and FR punishment effects. An additional purpose was to try to detect evidence that would indicate that Ss discriminated when shock would occur by the ratio of responses during FR 10 punishment. Visual inspection of the cumulative records for FR punishment on VI baselines in Experiment I did not reveal

Table 1

Response rates in responses per minute as a function of sessions. The "Punishment Alone" column represents rates during punishment without a warning while the "Punishment plus an S^D" column represents rates during punishment with a warning. In addition, the "Punishment plus and S^D" column is divided into "Overall Rate", which is simply the total responses emitted during the punishment with a warning condition divided by the total time in that condition, and the "Local Rate" in which the divisor is the time in which the S is actually responding. "Local Rate" takes pausing during the warning into account.

B 4172

FR Punishment

Session	Punishment Alone	Punishment plus an S^D	
		Overall Rate	Local Rate
1	39.2	15.2	60.4
2	42.3	27.5	67.3
3	37.1	30.8	65.3
4	37.5	33.1	62.1
5	35.2	35.3	64.2
6	36.4	34.9	75.2
7	33.9	29.8	65.8
8	31.65	33.3	57.9
Average	36.7	30.0	64.8

VR Punishment

Session	Punishment Alone	Punishment plus an S^D	
		Overall Rate	Local Rate
1	32.1	7.3	55.0
2	44.5	27.3	66.6
3	32.5	24.3	56.9
4	33.1	24.8	55.5
5	34.4	25.6	55.8
6	27.2	23.4	57.5
7	30.3	26.2	56.0
9	30.8	27.6	57.3
Average	33.1	23.3	57.6

B 1725

FR Punishment

Session	Punishment Alone	Punishment plus an S^D	
		Overall Rate	Local Rate
1	35.3	23.3	46.8
2	31.5	27.1	41.1
3	41.5	38.2	59.9
4	40.6	34.0	47.3
5	31.6	32.2	49.6
6	42.4	28.1	44.6
7	43.7	37.2	51.4
8	47.6	35.1	48.5
Average	39.3	31.9	48.7

VR Punishment

Session	Punishment Alone	Punishment plus an S^D	
		Overall Rate	Local Rate
1	25.7	19.2	28.4
2	24.9	17.8	25.9
3	30.4	32.2	38.8
4	30.8	27.9	37.3
5	23.3	29.4	41.3
6	40.3	25.1	35.8
7	28.7	28.8	42.1
8	34.6	27.4	36.2
Average	29.8	26.0	35.7

any pre-shock pausing, which would be expected if Ss were discriminating when shock would occur. In this experiment, a measure was devised to try to detect any slight pausing that might be present but not readily visible on cumulative records. This measure consisted of cumulating on two running time meters the time in the first 5 and the time in the second 5 responses of the FR 10 for each session, and then comparing these two totals. Any pre-shock pausing should be indicated by a relatively longer amount of time spent in the second half of the ratio.

METHOD

Subjects

The subjects in Experiment II were the same as in Experiment I.

Apparatus

The apparatus in Experiment II was also the same as in Experiment I.

Procedure

All parameters of the multiple schedule were the same as in Experiment I. Ss were first run 10 sessions without punishment. Punishment sessions were then run with VR punishment associated with the yellow key and FR punishment associated with the green key, as before. During each punishment session the first 40 minutes were run without punishment, and then two hours of punishment were run. The 40 minutes of no punishment at the beginning of each session allowed responding to recover from the previous day of punishment and was introduced to reduce the interaction between successive days of punishment. Three replications were run. In the first and third the shock intensity was increased on successive days while in the second the shock intensity was decreased on successive days. The order of intensities as they were

presented in milliamperes were 0, 3, 6, 9, 12, 15; 12, 9, 6, 3, 0; 3, 6, 9, 12, 15 for B1725 and the same for B4172 except that the highest intensity used for B4172 was 12 ma instead of 15 ma.

RESULTS

In Fig. 8 the time spect in the first half of the punishment fixed ratio minus the time spent in the second half of the fixed ratio is plotted in log minutes as a function of shock intensity. The dotted lines shown in the figure were fitted by eye.A positive value of this measure indicates that more time was spent in the first half of the FR than in the second half. As can be seen from Fig. 8 the values are positive and they increase as a function of shock intensity indicating a lower response rate after shock relative to before the shock. Thus, this measure offers no evidence that Ss were discriminating when shock would occur on the basis of a ratio of responses. Rather, it indicates a post shock suppression which increases as the shock intensity increases.

Figure 9 shows the total number of responses made during the punishment portion of each session as a function of the shock intensity during that session for FR punishment (dotted lines) and VR punishment (solid lines). The arrows indicate the direction that the intensity was changed in over successive sessions. It can be seen that VR punishment produced a greater punishment effect at all intensities, except at 3 ma for the second replication for B4172.

DISCUSSION

The results show that VR punishment produced a greater decrement in the response rate than FR punishment when compared on a multiple schedule. This finding is consistent with Azrin's (1956) finding that VI punishment produced a greater punishment effect that FI punishment.

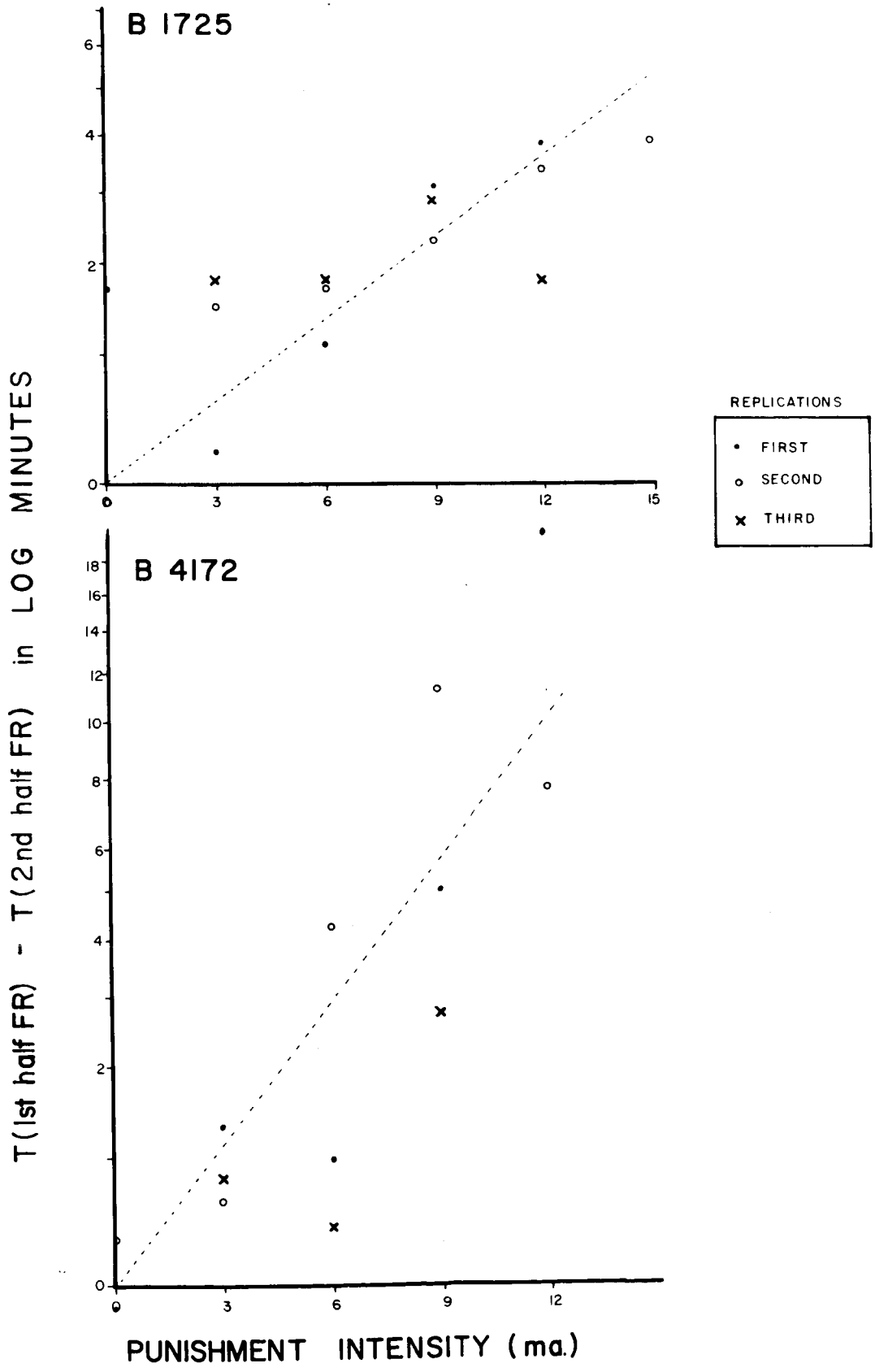

FIG. 8

The cumulative time in the first half of the FR punishment schedule minus the cumulative time in the seond half of the ratio expressed in minutes in log units as a func tion of shock intensity.

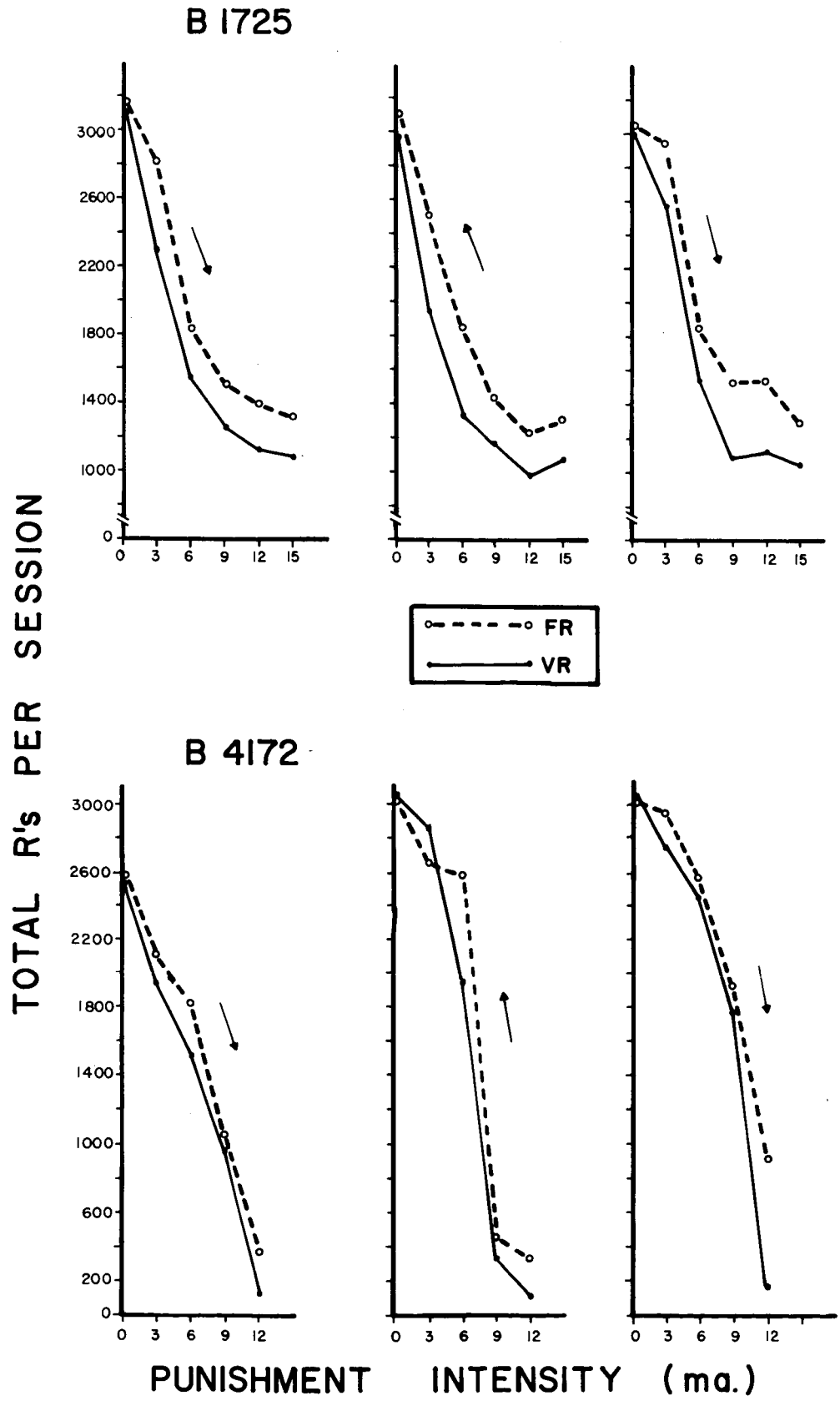

FIG. 9

Total responses in a session during FR punishment (dotted lines) and VR punishment (solid lines) as a function of shock intensity. Each point represent 1 hr. of experimental time.

Since the frequency of punishment for ratio schedules depends upon the number of responses emitted, the lower response rate during VR punishment resulted in fewer shocks during the VR schedule relative to the FR schedule. However, an equal number of reinforcements were received during VR and FR punishment. Thus, VR punishment produced a greater punishment effect with fewer shocks than FR punishment, and this effect was not confounded by a change in reinforcement frequency during VR punsihment.

One possible explanation for the difference between the effects of VR and FR punsihment is that the FR punishment allowed the Ss to discriminate when shock would occur whereas VR punishment would not. To test this possibility, the flasher or S^D for punishment was programmed for both VR and FR punishment in an attempt to make the occurrence of the punisher equally discriminable for the two schedules.

As was seen in the results section, VR punishment continued to have a greater effect on the response rate than FR punishment even after the S^D was added. This result cast some doubt on the hypothesis that the difference in the discriminability of when shock occurs during VR and FR punishment was the cause of the difference in the effectiveness of these schedules. Also, against such a hypothesis was the finding that during FR punishment alone there was no pausing before shock which might be expected if Ss were discriminating the occurrence of shock by the ratio of responses. On the contrary, pausing after the shock was found.

Alternative explanations for the different effects of fixed and variable schedules have been given. Herrnstein (1964) considers the different conditioned reinforcing effects of FI and VI reinforcement as

a problem in how Ss "average" the frequency of random events. For example, S's behavior on a VI reinforcement schedule may be equivalent to behavior on a FI of the geometric mean of the VI rather than equivalent to an FI of the arithmetic mean of the VI. That is, Ss may "judge" the frequency of reinforcement or punishment of a random distribution logrithmically rather than arithmetically, which is to say that the short inter-reinforcement intervals are weighted more heavily than the longer intervals. Although there is experimental support that Ss don't average arithmetically (Fantino, 1967; Galloway and Vogt, 1967) neither do these studies support a logrithmic interpretation.

In the present experiment, the addition of the warning stimulus did not change the probability of punishment although it did change the discriminability of when punishment would occur. The finding that the warning signal didn't change the relative effects of VR and FR punishment is interpreted as supporting Herrnstein's view that the differences in fixed and variable schedules should be considered as a problem of how Ss average the density of events in time.

It was found that the absolute punishment effect at various intensities was greater in Experiment II than in Experiment I (compare Fig. 1 and Fig. 9). This can be attributed to the difference in procedure between the two intensity studies. In Experiment I the intensity was increased in 1 ma increments each day whereas in Experiment II the intnesity was increased in 3 ma increments. Azrin and Holz (1966) have reported that when shock is increased gradually it has less of a punishing effect than when it is increased suddenly. In addition, in Experiment II there was a 40 minute warming up period with no punishment at the beginning of each session. This period was sufficient for recovery

of the non-punished response rate, and gave Ss a non-punished period against which various shock intensities could be contrasted, whereas in the first procedure shocks were contrasted with the previous day's intensity which was only 1 ma less.

The lower response rate during punishment with a warning compared to punishment alone was unexpected. Preference experiments have shown that Ss prefer warned to unwarned shocks (Lockard, 1963; Zill, 1967). In the present experiment it is possible that Ss would prefer warned punishment even though it produced lower overall response rate.

An analysis of the response rate during punishment with a warning showed that the lower response rate during this condition, relative to punishment alone, could be attributed to suppression, or the time the warning was on. Indeed the local rate, or rate when the warning stimulus was off, was quite high, in fact, higher than the non-punished VI rates, which were about 50 R/m. However, suppression in this experiment should be distinguished from the usual conditioned suppression procedure. In conditioned suppression the onset and offset of the CS are independent of responding. In the present experiment both the onset and the offset of the flasher were response contingent. In addition, conditioned suppression is measured by the number of responses during the CS while suppression in the present experiment is measured by the time the stimulus is on, since the first response during it terminated it.

Since the onset of the warning is response contingent, a conditioned punishment procedure is defined. Conditioned punishment would be shown by a reduction in response rate between warnings, which wasn't what was found. However, Hake and Azrin (1965) found a stable conditioned punishment effect using a neutral stimulus that was intermittently paired with shock. Several procedural differences may account for why

conditioned punishment was found in their experiment and not in the present experiment. One possibility is that CS and shock were intermittently paired in Hake and Azrin's experiment while they were cocntinuously paired in the present experiment. This does not seem the likely candidate, however, because, if anything, continuous pairing should produce a stronger conditioned punishment effect.

Perhaps the critical difference is that in Hake and Azrin's experiment the offset of the CS-shock pairs were non-response contingent while in the present experiment a key peck terminated the warning stimulus. Hunt and Brady (1955) and Hoffman and Fleshler (1965) have observed both quantitative and qualitative differences between Ss that had control over the termination of a warning stimulus and those that did not. Hoffman and Fleshler found more suppression for the non-contingent Ss in a yoked control procedure. Hunt and Brady observed that the CER animals in which the CS was not response contingent showed more emotional effects such as crouching, defecation, and freezing while the contingent (Punishment) animals moved around during the warning but made "abortive"lever presses. Similarly in the present experiment it was observed that during the flasher pigeons remained mobile and contined to peck, but that they pecked around the key rather than on it. This is in contrast to the usual CER paradigm in which during the CS pigeons were observed to go to the back of the cage, turn their back to the key and remain immobile (Orme-Johnson, 1967).

The lack of conditioned punishment in the present experiment may reflect a lack of conditioned aversiveness of the stimulus paired with shock using the response contingent procedure.

There are some good reasons for thinking of "emotional" effects in

terms of conditioned aversiveness. Emotional effects during the CER are often thought of as due to respondent or Pavlovian conditioning (Hunt and Brady, 1951 ; Kamin, 1965) and there is some indication that conditioned reinforcement may be a matter of Pavlovian conditioning (Ferster, 1953; Ferster and Skinner, 1957; Autor, 1960; Stein, 1958). Since the emotional effects of a stimulus paired with shock are greater when the offset of the shock is non-response contingent, the suggestion is that the conditioned aversive effects, as shown by conditioned punishment, would be greater using the non-contingent procedure.

By extention, when the frequency of reinforcement is held constant, one might expect a greater conditioned reinforcing effect for a stimulus during which the subject has no control overthe occurrence of primary reinforcement. Experimental varification of this possibility would be of considerable interest.

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